**1. Laser. (20%)**

Explain how these lasers work. (1) Ne-He laser; (2) Ruby laser; and (3) Diode laser.

Ans: Part (1)

The Ne-He laser is a type of gaseous laser. The Ne-He has four higher energy states above ground level and works. A RF generator excites the Helium and Neon gasses inside of a tube to higher energy levels. The excited atoms collide putting the Helium and Ne atoms at 20.61 eV and 20.66 eV above the ground state respectively. These collisions achieve a population inversion in the Neon atoms at 20.66 eV. Now when the excited Ne atom drops to a lower energy state 18.70 eV it emits a photon at 6328 Angstroms. As with other lasers, one end of the tube has a reflecting mirror with the other end consisting of a partially reflecting mirror gathers the photons and amplifies them before emitting.

Part (2)

The ruby laser has a three-level energy diagram that occurs because of the substitution of aluminum in a crystal of sapphire(ruby). Once the pumping scheme excites atoms to blue and green bands a population inversion is formed with the addition of a cavity produces our stimulated emission. The partially transparent mirror at the end of cavity allows the temporal coherent light (due to energy levels transitions being the same for all atoms) to emerge that also has spatial coherence owing to the tight collimation of the beam.

Part (3)

A Diode or Light-Emitting Diode laser shares some of the same physics as a diode. A diode is a material that is doped with impurities that cause part of the device to contain an excess of holes or electrons, p-type, or n-type material respectively. Now with a normal diode a bias voltage is applied that causes a migration of holes to electron causing extra electrons to fall into holes giving up energy in the form of photons.

**2. Laser safety. (20%)**

A CO2 laser (=10.6 m) with a power of 60 watts is projected onto a dilated human eye pupil of 6 mm diameter. The eye is exposed for a duration of 10 seconds. Calculate the minimum optical density OD of a laser safety goggle needed to protect the eye from damage.

Ans:

%---------------------------------------------------------------------

% file name : hmwk\_3\_prob\_2\_olaser.m

% Student: Ray Duran

% Date: 3/25/22

% Class : BME 690 Professor Liang, Spring Semester

% University of North Dakota

% Descr:

% Optical Sensor PMT

%---------------------------------------------------------------------

power = 60; % Watts

mpe = 0.1; % watts/ cm^2 for 10 s with a C02 laser

% A = pi\*r^2

% = 9pi\* mm^2 \* cm^2/ 100 mm^2

% = 9\*pi/100 cm^2

area = 9\*pi/100; % cm^2

avg\_power\_density = power/area;

OD = log10(avg\_power\_density/mpe);

OD = 3.3268

**3. Optical sensor (PMT). (20%)**

A PMT with 11 dynodes, with single dynode gain d =6, quantum efficiency is 25%. Yellow light (550 nm) strikes the photocathode and generate anode current 5 A. Calculate the incident light power.

Ans:

%---------------------------------------------------------------------

% file name : hmwk\_3\_prob\_3\_opitcal\_sensor.m

% Student: Ray Duran

% Date: 3/21/22

% Class : BME 690 Professor Liang, Spring Semester

% University of North Dakota

% Descr:

% Optical Sensor PMT

%---------------------------------------------------------------------

qe = .25; % quantum efficiency

% All of this is electrons / sec

I = 5e-6;% C/S

electrons = I\*6.24e18; % C\* electrons/C

photons = electrons/qe; % Photons at photocathode?

E = (3e8)\*(6.62607015e-34)/(550e-9); % Joules one photon h\*c/lambda

total\_energy = photons\*E;

% And since this is all in one second

power = total\_energy;

Total energy = 4.5105e-5 W

**4. Optical sensor (area sensor). (20%)**

You are asked to build a digital microscope (Figure 1) to image small beads (diameter = 1 m), but you are only provided an objective (10×, 0.5NA) and a tube lens (*f*=200mm). Now you need to choose a monochrome camera from Edmund optics catalog (https://www.edmundoptics.com/f/basler-ace-usb-30-cameras/14831/).

(1) If you only need to consider the spatial resolution, which one will you use? Describe how you will choose it.

(2) Do you think Camera **Stock #11-498** (720 × 540 pixels, pixel size: 6.9×6.9 m) will do the job? Why?



Figure 1 Digital microscope diagram

Ans (1)

%---------------------------------------------------------------------

% file name : hmwk\_3\_prob\_4\_opitcal\_sensor.m

% Student: Ray Duran

% Date: 3/24/22

% Class : BME 690 Professor Liang, Spring Semester

% University of North Dakota

% Descr:

% Optical Area Sensor

%---------------------------------------------------------------------

lambda = 550e-9; % wavelength of visible light

num\_aper = .5;

ray\_criterion = .61 \*lambda/(num\_aper);

resolution = .67 um

So, we can resolve the bead which is 1 um

So, now we magnify by 10 would give and that gives us 6.7um

Now, any camera with a pixel resolution smaller than 6.7 um should work.

## Pick [Basler ace acA1440-220um USB 3.0 Monochrome Camera](https://www.edmundoptics.com/p/basler-ace-aca1440-220um-usb-30-monochrome-camera/40359/)

Stock **#11-500**

With a pixel size of 3.45x3.45 um and it should work

Ans (2)

The 6.9x6.9 um should not work because it is larger than the magnified resolution.

**5. Polarization (20%)**

Use calcite to make a quarter-wave plate (designed for light =590 nm). (1) What is the minimum thickness of this quarter-wave plate? (2) If a right-hand circular polarized light passes through this wave plate, what is the polarization state of the emerging light? Use Jones matrix method to calculate and explain it.

Ans:

%---------------------------------------------------------------------

% file name : hmwk\_3\_prob\_5\_polarization.m

% Student: Ray Duran

% Date: 3/22/22

% Class : BME 690 Professor Liang, Spring Semester

% University of North Dakota

% Descr:

% Polarization

%---------------------------------------------------------------------

lambda = 590e-9; % wavelength

% Use values from lecture where lambda = 589.3 nm

% for approx. lambda = 590 nm

ne = 1.4864; % for Ey

no = 1.6584; % for Ex

d = lambda/(4\*(abs(ne-no))); % for a quarter wave plate

% If RHCP light passes thru above wave plate

% nx > ny

AQWP = [ 1 0; 0 1i];

%RHCP light

rhcp\_light = (1/sqrt(2)).\*[ 1; -1i];

Emerge\_light\_polarization = AQWP\*rhcp\_light;

Ans part a:

So, d = .85756 um

Ans part b:

Emerging light is 1/sqrt(2) [ 1; 1;]

This means that the RHCP light was rotated into linear 45 degree polarized light.